CHAPTER 7 TRANSMISSION LINE DESIGN CRITERIA

7.1 GENERAL

The design criteria of a transmission line sets the detailed design characteristics. The design criteria is critical as it will be instrumental in conductor and structure design. The primary components of a design criteria are the electrical and mechanical loadings. Mechanical loading is a result of loads generated by weather and construction activities. Electrical loading is a result of the manner in which the line is operated and lightning events and dictates electrical clearances, insulation levels, and grounding.

The importance of a sound design criteria cannot be overstated as it will determine the reliability and the ultimate cost of the line. The goal of a design criteria analysis is to define a particular reliability level for the line (electrically and mechanically) and then determine the costs to increase that level.

For purposes of this study, analysis was performed for the location and requirements of the line for 500kV AC operation and a reasonable criteria is proposed. Further study is appropriate to determine costs to adjust that reliability.

7.2 MECHANICAL LOADING

The Townsend-Borah/Midpoint transmission line is located within the NESC Medium Loading zone. However, NESC Heavy loading conditions are recommended for the 500kV line because of the need for increased reliability at the higher voltage. This also matches Northwest Energy's Colstrip 500kV lines which were designed for NESC Heavy conditions. The Townsend-Midpoint project study area encompasses some mountainous terrain as well as high grassy valleys, canyons and arid plains with elevation ranges estimated between 3500 and 6500 feet.

Glaze ice loadings up to 0.25" and cold temperatures as low as -40 degrees may be reasonably encountered along the line within a 50 year return period. At 17 weather stations that were queried along the general line route as reported by the Western Regional Climate Center (WRCC), the average total snowfall for any one month in a 74 year period was found to be less than 5". Also, extreme wind speeds were queried for weather stations as reported for the National Science Foundation (NSF march 1979) as well as the WRCC, that were close to the line route. These sources indicate that both the fastest mile and peak wind gust speeds may not exceed 70-80 mph in a 50 year return period. To match the criteria of the Colstrip lines, a 100mph extreme wind load is recommended. Further ice and wind studies are recommended to determine the adequacy of the design criteria to follow.

7.3 500kV TOWER DESIGN CRITERIA

In determining the tower design criteria, Northwest Energy practices and standards were reviewed. The Colstrip lines were investigated for loading and geographic location to determine the pertinence of that line design as applied to this study.

The following preliminary mechanical design criteria is proposed for all of the single circuit towers. This criteria forms a basis for further refinement as design is initiated and special geographically confined loading areas may be defined which require modified criteria.

Table 7.3-1 500kV Tower Design Criteria

Loading Condition	Wire Wind Pressure	Tower Wind Pressure[1]	Ice	Temperature[2]
NESC Heavy	4 psf	6.4 psf	½"	0°F
Extreme Wind	25.6 psf	64.0 psf (Applied on T and L faces)	None	60°F (Final)
Stringing (2:1 h/v)	2 psf	3.2 psf	None	0°F
Heavy Ice and Wind	2 psf	6.4 psf	1"	0°F (Final)
Broken Wire (any 1 shield wire or opgw or phase simultaneously broken on one side only)	2 psf	6.4 psf	None	0°F (Final)

[1] Wind Pressure is increased by a shape factor of 1.6 and applied to both front and back face of latticed tower members so that the overall shape factor is 3.2 on the sum of the projected areas. (See NESC 252.B.2.) For cylindrical steel shafts and members, the tower wind pressures above shall be divided by 1.6.

[2] Loading Condition is at initial tension unless otherwise noted.

Table 7.3-2 Design Loading Overload and Safety Factors:

Loading Condition	Vertical	Transverse	Longitudinal
NESC Heavy	1.5	2.5 Wind 1.65 Tension	1.65
Stringing (2:1 h/v)	1.5 (tension and weight)	1.5	1.5
Heavy Ice and Wind	1.0	1.0	1.0
Broken Wire (any 1 shield wire or opgw and phase simultaneously broken on one side only)	1.1	1.1	Susp/Tan – 1.25 At deadends – NA
Extreme Wind	1.1	1.1	1.1

7.4 WIRE TENSION LIMITS

The following tension limitations are applied in the calculation of sag and tension data for the anticipated conductor and shield wire used in the cost estimating and which will likely be deemed to be most cost effective for the project. A 1590 ACSR "Lapwing" conductor and 7/16" EHS shield wire is assumed. In determining the proposed tension limits, past experience with the conductor were considered.

POWER's experience with conductor design suggests a vibration limit of approximately 9100 lbs at 0 degrees Fahrenheit. This suggests a safe tension limit for the conductor for vibration related concerns. The shield wire tension is chosen to be approximately 80% of the conductor sag at 60° F initial as is typical for transmission design. A ruling span of 1500 ft is assumed for estimating purposes. The ruling span will ultimately be a function of the terrain and design criteria.

The following are recommended conductor sag and tension limits:

Table 7.4-1 Design Loading Overload and Safety Factors:

Load Case	Conductor Tension Limits	Shield Wire Tension Limits[1]
NESC Heavy Loading District (4 psf wind, 0° F, Initial)	17,000 lbs.	7250 lbs.
Heavy Ice and Wind (1" Ice, 2psf Wind, 0° F, Final)	21,100 (50% of ultimate strength)	10, 400 lbs.
Vibration Limits (0° F, Final)	9318 lbs. (Tension/Mass = 5200 ft.)	3744 lbs.
Extreme Wind (100psf Wind, 60° F, Final)	17,000 lbs.	7250 lbs.

[1] An OPGW will be chosen as required that will match the sag of the shield wire at 60°F initial. It is anticipated that the OPGW tensions will exceed that of the shield wire so that determination of the OPGW type and size will need to be made prior to generation of structure mechanical loadings.

Additional loading conditions and a more detailed design criteria discussion included in Appendix B.

7.5 ELECTRICAL LOADING

The electrical design of the transmission line is dictated primarily by the operation of the line and the geographic location. Lightning analysis and switching surges will dictate what electrical parameters will be required for the tower design. The basic insulation level (BIL) for the line will be the result of this analysis. The transmission line components impacted by this are the conductor insulators, air gap, ground clearance, and grounding.

Insulation - Insulation at 500kV typically is on the order of a 22-25 bell equivalent. The most recent 500kV lines (Path 15, Nevada Power) in the west have utilized polymer insulators. The use of polymer insulators for strain insulators is mixed, some utilities are using porcelain for deadend applications. Polymer insulators have performed well historically and their cost is significantly less than porcelain equivalents in material and installation cost.

Structure Air Gap - The conductor to structure clearance (air gap) is also part of the BIL analysis. At 500kV, this clearance will likely be overridden by larger clearances necessary dictated by live line working techniques. These clearances are designed into the structure to allow the energized transmission line to be worked on from the structure with insulated equipment.

Ground Clearance – Minimum NESC ground clearance for 500kV is 30 feet. It is recommended that a minimum of 35 feet of basic ground clearance is designed for, which is consistent with recent 500kV project design practice.

Grounding - The isokeuronic level needs to be evaluated in detail to determine the grounding of the transmission line. It is expected that a segmented shield wire system will be utilized for the project.